

# Learning to avoid spiders: fear predicts performance, not competence

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## ABSTRACT

We used an immersive virtual environment to examine avoidance learning in spider-fearful participants. In 3 experiments, participants were asked to repeatedly lift one of 3 virtual boxes, under which either a toy car or a spider appeared and then approached the participant. Participants were not told that the probability of encountering a spider differed across boxes. When the difference was large (Exps. 1 and 2), spider-fearfuls learned to avoid spiders by lifting the few-spiders-box more often and the many-spiders-box less often than non-fearful controls did. However, they hardly managed to do so when the probability differences were small (Exp. 3), and they did not escape from threat more quickly (Exp. 2). In contrast to the observed performance differences, spider-fearfuls and non-fearfuls showed equal competence, that is comparable post-experimental knowledge about the probability to encounter spiders under the 3 boxes. The limitations and implications of the present study are discussed.

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Avoidance is a key element of anxiety disorders. According to theories of anxiety, avoidance is not only a symptom of anxiety, but it is also crucial in developing and maintaining the symptoms of anxiety (Rachman, 2004; Williams, Watts, MacLeod, & Mathews, 1997). Two-stage theories of fear and avoidance propose that fear of threat motivates avoidance responses. When avoidance responses are successfully executed, the level of fear is reduced, and as a result, the avoidance responses are strengthened by negative reinforcement (Mowrer, 1939; Rachman, 1976). However, while avoidance may reduce anxiety in the short term, it is often maladaptive in the long term (Rachman, 2004), as it may significantly restrict one's daily life and maintain anxiety and phobias. In the present experiments, we examined avoidance responses in samples with and without fear of spiders, to further understand aspects of competence and performance in the learning of avoidance behaviour. Here, we use the term "avoidance responses" as a generic term for two different responses: *escape* and *avoidance*. *Escape* is a reaction to ongoing aversive

events, for instance, spider phobics may exit a room quickly if they encounter a spider in it. In contrast, *avoidance* aims to reduce the probability that an aversive event will occur. For instance, spider phobics will not enter a room that is known to contain spiders (Krypotos, Effting, Kindt, & Beckers, 2015; Lovibond & Rapee, 1993). It is particularly this preventive function of avoidance behaviour that the present experiments addressed.

As a subtype of anxiety disorders, specific phobia is defined as the unreasonable and irrational fear of a specific object or situation, and it is found in the general population with high prevalence (LeBeau et al., 2010). Since spider phobia is frequent and often considered a "model" phobia for specific phobia in general, it was investigated here. Avoidance responses of spider phobics have been observed with diverse paradigms in a large number of studies. However, the studies were almost always limited to the category of escape behaviours. For instance, spider-fearful people exhibit escape tendencies in attentional behaviour when they look away from

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spider pictures more quickly than non-fearful controls do (Pflugshaupt et al., 2005; Rinck & Becker, 2006). Escape behaviours are also easily observed in Behavioural Assessment Tests (BAT). In these tests, spider-fearful participants regularly keep a larger distance from a real spider than non-fearful controls do, and this is true for both adults and children (e.g. Garcia-Palacios, Hoffman, Carlin, Furness, & Botella, 2002; Klein, 2011). In addition to this controlled escape behaviour, spider-fearful participants also display escape tendencies when reacting more automatically (Rinck, Kwakkenbos, Dotsch, Wigboldus, & Becker, 2010). For instance, in the Approach-Avoidance Task (AAT; Rinck & Becker, 2007), spider-fearful participants were faster to push pictures of spiders away than to pull them closer, even when asked to ignore the contents of the pictures.

Although it has been demonstrated that spider fearfuls try to escape from spiders both attentionally and behaviourally, both consciously and automatically, these studies are limited to escape situations, while hardly any study addressed avoidance (although authors often use the term “avoidance” when they actually study escape). Thus, we know that spider fearfuls will try to get away from a spiders, but what would they be willing to do to make sure they will not encounter a spider in the first place? Pittig, Brand, Pawlikowski, and Alpers (2014) addressed this question with the “Spider Gambling Task”, a variant of the Iowa Gambling Task. They found that spider-fearful participants were willing to make financially disadvantageous choices (choosing cards with a higher probability to lose fictitious money), in order to avoid looking at and clicking on cards that were labelled with pictures of spiders. Strictly speaking, this behaviour is difficult to classify; it contains aspects of both avoidance and escape, because the spider pictures were constantly presented in the participants’ visual field. A virtual reality study by Rinck et al. (2015) gives a more evident example of avoidance of forthcoming events by spider fearfuls. In this study, participants walked around freely in a small virtual museum in search for specific paintings. Unbeknown to the participants, two of the four museum rooms contained virtual spiders. It was found that within a few trials, spider-fearful participants learned to avoid the two rooms containing spiders by developing a preference to start their search in the two “safe” rooms. How quickly participants learned to avoid the spider rooms was correlated with their level of spider fear.

The study by Rinck et al. (2015) provided evidence of avoidance and avoidance learning in highly fearful participants in a controlled laboratory environment. However, an important issue has not been examined yet: the distinction between *competence* and *performance* in the learning process (Wood & Power, 1987). Competence refers to the knowledge and abilities people have, for instance, knowing the rules of a language (Chomsky, 1965) or knowing how to beat a bobo doll (Bandura, 1965). In contrast, performance refers to the actual execution of behaviour in a specific situation, for instance, using one’s knowledge of a language in a real conversation (Chomsky, 1965) or actually beating a bobo doll in a study on imitation learning (Bandura, 1965). Thus, performance usually reflects competence (except in random trial-and-error behaviour), but non-performance does not indicate non-competence (not showing a certain behaviour does not mean inability to show it). As a result, a discrepancy in performance does not have to indicate a discrepancy in competence. In most of studies of avoidance responses by phobics, participants’ performance was measured, but their competence was usually ignored. For instance, Rinck et al. (2015) found that spider-fearful participants avoided rooms with spiders more than non-fearful controls did, but it is still unknown whether this difference in performance reflected a difference in competence: Did the non-fearfuls know less about the location of spiders, or did they learn it as well as the spider-fearfuls, but just did not bother to use this knowledge because they felt no need to avoid spiders?

To address the difference between performance and competence, the present study was designed to answer the following questions: (1) Do highly spider-fearful participants (in short, spider-fearfuls) and non-spider-fearful participants (in short, non-fearfuls) show a difference in avoidance and escape behaviours, that is, in their performance? (2) Do spider-fearfuls and non-fearfuls show a difference in their level of knowledge underlying the avoidance behaviour, that is, in their competence? These questions were addressed in three experiments with the help of an “immersive virtual environment” (IVE). Furthermore, compared to earlier studies, a more variable threatening environment was presented to participants. Here the appearance of spiders was more stochastic than in the environment used by Rinck et al. (2015), making it more difficult for participants to predict when and where a spider would appear. Finally, the present experiments were also designed to further

validate the use of IVEs in the study of fear-related behaviour.

In each of the three experiments reported here, participants were sitting in front of a real table, holding a box with three buttons in their hands and wearing a head-mounted display. On the display, they saw a virtual copy of the real table with three virtual boxes on it, positioned on the left, the middle and the right side of the table. Participants were instructed to lift the boxes by pressing the corresponding button on the button box. Each time they lifted a box, an object under the box became visible and then moved towards the participant. The object could be either a spider or a toy car. Unbeknown to participants, one box was a “safe” box containing very few spiders (with a 10% probability to reveal a spider and a 90% probability to reveal a toy car), one box was an almost “neutral” box (40% spider probability, 60% toy car probability) and the third one was a “threat” box containing mostly spiders (90% spider probability, 10% toy car probability). We used 10%, 40%, and 90% instead of 0%, 50%, and 100%, respectively, for two reasons: First, we tried to simulate realistic environments which usually are neither 100% spider-free nor 100% spider-infested. Second, the chosen probabilities made it more difficult to guess the correct values by simply naming prototypical percentages often used in experiments. In each trial, participants had to lift a single box, and they were completely free to decide which box to lift. During the experiments, we measured participants’ behaviour by counting how often they lifted each box. Based on previous findings, we predicted that spider-fearfuls would learn to avoid spiders by lifting the safe box more often and the threat box less often.

After the experiments, participants’ knowledge was probed by asking them to indicate the probability to see a spider under each box. In this way, we hoped to reach more insight into the distinction between competence and performance in avoidance learning. We aimed to test three alternative hypotheses regarding the relation of competence and performance in spider fearfuls: The *equal-learning hypothesis* predicts that spider-fearfuls and non-fearfuls acquire comparable knowledge (competence), but differ in their motivation to apply it for avoiding spiders (performance). In contrast, the *improved-learning hypothesis* states that the spider-fearfuls’ aim to avoid spiders also motivates them to better learn where to expect them. Finally, the *selective-learning hypothesis* predicts that if participants develop a preference for lifting a

specific box, their estimates of the spider-probability of this box will become more precise whereas their estimates of the other boxes will become less precise.

## Experiment 1

This experiment was conducted as a first test of spider-fearfuls’ performance in a stochastic threat situation. In an IVE, they had the chance to learn that some actions yielded a lower chance of exposure to threat (i.e. lifting a “safe” box which hardly ever contained a spider) while other actions yielded a high chance (i.e. lifting a “threat” box that almost always contained a spider). Our main question was if they would learn this difference (competence), and if yes, if and how quickly they would use it to avoid the virtual spiders (performance). With regard to performance, we expected spider-fearfuls to show generally more avoidance of spiders than non-fearfuls, by lifting the safe box more often and the threat box less often. We also expected that as spider-fearfuls completed more trials and gained more knowledge about the boxes, they would encounter fewer and fewer spiders. In contrast, non-fearfuls should not show a significant reduction of the number of spiders encountered during the task. With regard to competence and post-experimental knowledge of the probabilities, the study was exploratory, designed to test the equal-learning hypothesis against the improved-learning hypothesis and the selective-learning hypothesis.

## Methods

### Participants

To determine the necessary number of participants, we first conducted a power analysis using the programme G\*Power 3 (Faul, Erdfelder, Lang, & Buchner, 2007). As described below, the most critical analyses in all experiments involve  $2 \times 2$  mixed-factors interactions (for instance, a group-by-box interaction on the number of spiders seen). To find a medium-sized interaction of this sort with power of  $1-\beta = .8$ , a repeated-measures correlation of  $r = .3$ , and a conventional alpha error of  $p = .05$ , 46 participants are needed per experiment. Therefore, we pre-screened 97 female students (mean age 19.6 years, range 17–24) of Radboud University Nijmegen, using the Dutch version of the Spider Anxiety Screening (SAS; Rinck et al., 2002). From these, we selected 29

highly spider-fearful participants (min SAS scores = 20, max = 24, mean = 21.6, SD = 1.3) and 21 non-fearful ones (min SAS score = 1, max = 9, mean = 3.4, SD = 2.8), using the same cut-off scores of the SAS as in previous studies (e.g. Rinck et al., 2015). They were invited to participate, and they continued to the IVE. Spider-fearfuls did not differ from non-fearfuls in age,  $t(48) = 1.74$ ,  $p = .09$ ,  $d = .49$ ,<sup>1</sup> but significantly in SAS scores,  $t(48) = 30.66$ ,  $p < .001$ ,  $d = 8.8$  (the latter difference is extreme large but trivial, because we selected extreme groups according to the SAS scores).

### *Procedure*

Participants first gave written informed consent. They were then brought to the virtual reality lab and the IVE part started. This part took about 20 min. After that, participants filled in a short questionnaire to assess their knowledge of the probabilities to encounter a spider. The whole experiment took approx. 40 min.

### *Spider anxiety screening*

A Dutch translation of the Spider Anxiety Screening (Rinck et al., 2002) was used to select spider-fearfuls and non-fearfuls as participants. It consists of five statements, for which participants indicate to which extent they agree with each statement on a 7-point Likert scale (0 to 6).

### *The state-trait anxiety inventory (STAI)*

To test whether the IVE situation was valid and threatening enough, participants completed the state version of the STAI (Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983) both before and after the IVE task. In all three experiments described below, we found that spider-fearfuls' state anxiety was significantly higher than non-fearfuls' anxiety (with large effect sizes of  $\eta^2 > .20$ ), both before and after the IVE task. Detailed results are available from the first author.

### *Immersive virtual environment (IVE)*

The experiment took place in the Radboud Immersive Virtual Environment Research lab (RIVERlab). Participants were seated in front of a table while wearing a head-mounted display (HMD) and holding a button box on their laps. The button box had three buttons, arranged from left to right. After participants put on the HMD, they saw the virtual environment with a room of the same size as the RIVERlab. In front of them, they saw a virtual table which replicated the real table in front of them. On the virtual table, they

saw three closed wooden boxes placed on the left side, in the middle, and on the right side of the table. Pressing a button on the button box would lift the corresponding virtual box on the table by approx. 30 cm.

Each trial started with the appearance of the three boxes and a beep. Participants were asked to press one button on the button box to lift one box for each trial after they heard the beep. When the box was lifted, either a tarantula-sized virtual spider (black and approx. 10 cm long) or a virtual toy car of similar size (in red colour) appeared. The object approached the participant and stopped approx. 30 cm away from her, shortly before reaching the edge of the table. After that, the object and the boxes disappeared automatically and the next trial could be started. Each trial lasted for approx. 7 s. The task started with three practice trials, in which participants were instructed to press each button once to lift every box once. The toy car always appeared in these practice trials, which were followed by 60 experimental trials. Participants were explicitly told that in each of these trials, they were completely free to decide which box to lift.

Unbeknown to the participants, one of the boxes was a "threat box" (TB: containing 90% spiders), one was a "safe box" (SB: 10% spiders) and the third one was a "neutral box" (NB: 40% spiders). For the latter, we chose 40% instead of 50% to make it more difficult to guess the correct percentage. The position of the three boxes on the table was counter-balanced across participants. Importantly, after 30 trials, the percentages of the SB and the TB were exchanged without informing participants. This way, whichever box happened to be the SB during the first half of the experiment now became the TB and vice versa, while leaving the percentage of the NB unchanged. This manipulation allowed us to study re-learning of avoidance in addition to initial learning.

### *Knowledge check*

To assess participants' knowledge about the likelihood to encounter spiders under each box, they completed a short questionnaire. Separately for the two halves of the experiment, they had to indicate the percentage of spiders and the percentage of cars that had come out of the left, middle, and right box. These six spider percentages estimated by the participant were used as an index of her competence, i.e. her knowledge of the probability to encounter a spider.

## Results

### *Was avoidance exhibited and did it reduce the number of spider encounters?*

In this experiment, the most effective way to avoid spiders is by opening the SB and not opening the TB. To find out whether spider-fearfuls used this strategy more often than non-fearfuls, we analyzed how often each box was chosen by each participant. These numbers were subjected to a repeated-measures ANOVA with the between-subjects factor "group" (spider-fearfuls vs. non-fearfuls) and the within-subjects factor "box" (SB vs. TB). The neutral box was left out of this analysis because its inclusion would have violated the assumption of independent measures: Once the number of chosen SBs and TBs is known, the number of chosen NBs is determined because the total is always 60. The  $2 \times 2$  ANOVA yielded the expected significant interaction of group and box,  $F(1,48) = 18.89$ ,  $p < .001$ ,  $\eta^2 = .28$ . Moreover, follow-up tests revealed that spider-fearfuls preferred to lift the SB over the TB,  $t(28) = 6.29$ ,  $p < .001$ ,  $d = 3.42$ , while non-fearfuls did not show any preference,  $t(20) = .05$ ,  $p = .96$ ,  $d = .03$  (see Table 1). Hence, in line with our expectation, only spider-fearfuls showed an avoidant choice strategy during the task. Moreover, this strategy was successful: Across the 60 trials of the task, spider-fearfuls encountered fewer spiders than non-fearfuls, namely an average of 22.3 spiders

( $SD = 4.3$ ) compared to 27.5 ( $SD = 4.0$ ),  $t(48) = 4.36$ ,  $p < .001$ ,  $d = 1.25$ .

### *How did avoidance develop over time?*

The analyses reported above suggest that across the whole task, spider-fearfuls showed avoidance of spiders. To better understand how this avoidance developed during the task, we divided the 60 trials into 6 blocks of 10 trials each (i.e. 3 blocks in the first half and 3 blocks in the second half). For each block of 10 trials, the probability of encountering spiders (PES) was calculated by means of the following formula:

Probability of Encountering spiders

$$\begin{aligned} & \text{frequency to lift SB} \times 0.1 \\ & + \text{frequency to lift NB} \times 0.4 \\ & + \text{frequency to lift TB} \times 0.9 \\ & = \frac{\quad}{10} \end{aligned}$$

For instance, if in a block of 10 trials, a participant lifts the SB 8 times, the NB once, and the TB once, the participant's PES for this block is  $(8 \times 0.1 + 1 \times 0.4 + 1 \times 0.9)/10 = 21\%$ . The PES reflects an objective and unbiased index of the probability of encountering spiders. In the following analyses (also in Exp. 2 and 3), we analyzed arcsine transformed PES scores, as suggested by Cohen and Cohen (1983) and Winer (1971). However, to increase comprehensibility, we present the PES scores in the tables. To determine the time course of avoidance learning, a repeated-measures ANOVA with PES as the dependent variable was computed (see Table 1), using "half" (first vs. second) and "block" (1 vs. 2 vs. 3) as within-subjects factors and "group" as between-subjects factor. We found significant main effects of block,  $F(2,96) = 6.50$ ,  $p = .002$ ,  $\eta^2 = .12$ , and of group,  $F(1,48) = 19.82$ ,  $p < .001$ ,  $\eta^2 = .29$ , but no main effect of half,  $F(1,48) = 2.72$ ,  $p = .11$ ,  $\eta^2 = .05$ , nor any significant interaction (all  $p > .08$ ). These findings suggest that overall, spider-fearfuls had a lower probability to encounter spiders than non-fearfuls had, and that there were significant differences between blocks. However, the temporal development of PES did not differ significantly between the two groups.

We also tested our hypothesis that the PES would decrease across blocks for spider-fearfuls, but not for non-fearfuls. Therefore, we conducted four repeated-measures ANOVAs including within-subjects contrasts, separately for each combination of group and task half. The contrasts revealed a negative linear trend

**Table 1.** The mean number of lifted boxes, the probability of encountering spiders (PES), and the estimated PES for each box, for spider-fearfuls and non-fearfuls in Experiment 1.

	Spider-fearfuls (SD)	Non-fearfuls (SD)
Lifted SB	26.7 (6.6)	21.1 (5.0)
Lifted TB	14.3 (4.6)	21.0 (4.4)
PES in Block 1 (%)	39.1 (7.5)	48.6 (7.2)
PES in Block 2 (%)	36.7 (10.1)	45.0 (9.4)
PES in Block 3 (%)	36.0 (11.7)	44.8 (10.4)
PES in Block 4 (%)	45.7 (8.4)	47.3 (9.0)
PES in Block 5 (%)	37.9 (11.0)	50.5 (14.2)
PES in Block 6 (%)	36.2 (14.2)	45.3 (15.6)
Estimated PES in SB (%) in 1st half	24.7 (15.9)	30.0 (17.3)
Estimated PES in NB (%) in 1st half	41.5 (17.9)	33.8 (15.4)
Estimated PES in TB (%) in 1st half	64.2 (24.4)	68.1 (18.0)
Estimated PES in SB (%) in 2nd half	30.7 (19.1)	36.0 (19.8)
Estimated PES in NB (%) in 2nd half	49.9 (16.3)	45.7 (15.4)
Estimated PES in TB (%) in 2nd half	64.2 (20.0)	64.3 (18.9)

Note: SB = Safe Box, NB = Neutral Box, TB = Threat Box.



of PES in spider-fearfuls in both halves of the task (first half:  $F(1,28)=4.15$ ,  $p=.05$ ,  $\eta^2=.13$ ; second half:  $F(1,28)=12.16$ ,  $p=.002$ ,  $\eta^2=.30$ ), indicating that for spider-fearfuls, the PES decreased linearly, even after the secret box-swapping. In contrast, no significant trends were found for non-fearfuls in either of the halves.

Additionally, a MANOVA was conducted to further investigate differences between spider-fearfuls and non-fearfuls in each block. Spider-fearfuls had a significantly lower probability of seeing spiders in almost all blocks (Block 1:  $F(1,48)=20.06$ ,  $p<.001$ ,  $\eta^2=.30$ ; Block 2:  $F(1,48)=8.49$ ,  $p=.005$ ,  $\eta^2=.15$ ; Block 3:  $F(1,48)=7.31$ ,  $p=.009$ ,  $\eta^2=.13$ ; Block 5:  $F(1,48)=12.19$ ,  $p=.001$ ,  $\eta^2=.20$ ; Block 6:  $F(1,48)=4.15$ ,  $p=.05$ ,  $\eta^2=.08$ ). The only exception was Block 4, directly after the SB and the TB had been switched ( $F(1,48)=.45$ ,  $p=.51$ ,  $\eta^2=.009$ ). Here, spider-fearfuls took a while to adjust their previously successful avoidance strategy by reversing their choices of the SB and TB.

### *Were there differences in competence?*

Spider-fearfuls' and non-fearfuls' knowledge of the PES for each box in each half was analyzed with a repeated-measures ANOVA with "group" (spider-fearfuls, non-fearfuls) as between-subjects factor, and half (first, second) and box (SB, NB, TB) as within-subjects factors, using the post-experimental percentage estimates as the dependent variable. The ANOVA yielded a significant main effect of box,  $F(2,96)=69.43$ ,  $p<.001$ ,  $\eta^2=.59$ , because both groups correctly knew that in both halves, the TB contained more spiders than the NB, which in turn contained more spiders than the SB (see Table 1). In contrast, there was neither a significant main effect of group nor any interaction with this factor, all  $F<1.19$ ,  $p>.16$ ,  $\eta^2<.04$ , indicating that compared to non-fearfuls, spider-fearfuls did not overestimate the overall probability to encounter spiders, nor were they more correct in estimating the percentage of spiders located under each box. In fact, inspection of the means shown in Table 1 shows that the two groups behaved very similarly: They overestimated the PES for the safe box and underestimated the PES for the threat box.

### *Discussion*

The results of Experiment 1 demonstrate avoidance learning in spider-fearfuls. They quickly learned to lift

the safe box more often than the threat box, while no such preference occurred in non-fearfuls. Consequently, spider-fearfuls encountered fewer spiders than non-fearfuls during the task. After the secret switch of the safe box and the threat box, spider-fearfuls could adapt their choices to reflect the new probabilities, and they exhibited avoidance during the second half of the task, too. In contrast, non-fearfuls did not show any evidence of avoidance of spiders, their choices seemed independent of the probability of encountering spiders. These differences in performance occurred in the absence of any measurable differences in competence: Spider-fearfuls and non-fearfuls had similar knowledge about the probability of encountering spiders under each box. Both groups over-estimated the percentage of the safe box, and under-estimated the percentage of the threat box. Also, both groups realised the differences between the three boxes, and the change in percentages in the middle of the experiment. In sum, the results of Experiment 1 are best accounted for by the equal-learning hypothesis: They suggest clear differences in performance in the absence of differences in competence. It seems that both groups knew similarly well where to expect more spiders, but only spider fearfuls used this knowledge to avoid spider encounters.

### **Experiment 2**

The main goals of Experiment 2 were to replicate the findings of Experiment 1, and to examine escape behaviour in addition to avoidance behaviour. Hence, in Experiment 2, participants were given the opportunity to end encounters with spiders quickly, in addition to avoiding them in the first place. To achieve this, they could press a termination button to make the approaching object, no matter whether a virtual spider or a virtual toy car, disappear immediately. We expected spider-fearfuls to use this escape possibility by pressing the termination button more often and more quickly in response to approaching spiders than toy cars. We also aimed to replicate the main results of the first experiment: Spider-fearfuls should show more avoidance of spiders than non-fearfuls by lifting the safe box more often and the threat box less often, thereby reducing the probability to encounter spiders. Regarding competence, we expected that – as in Experiment 1 – the two groups would show similar knowledge of the probability to encounter spiders under the 3 boxes.

## Methods

### Participants

Eighty-four students (mean age 20.8 years, range 18–28, one participant did not give her age) of Radboud University Nijmegen were recruited for the pre-screening with the SAS (Rinck et al., 2002). From these, 24 spider-fearful participants (mean SAS score = 19.5, SD = 2.5) and 24 non-fearful ones (mean SAS score = 3.1, SD = 2.1) were selected. Based on the large effect size observed in Exp. 1 ( $\eta^2 = .28$ ), only 18 participants in total were needed to reach sufficient statistical power. However, because of the possibility to escape from spiders, we expected a smaller effect size in Exp. 2. Hence, we decided to have a similar sample size as in Exp. 1, to make the two experiments more comparable. Again, spider-fearfuls and non-fearfuls did not differ in age,  $t(45) = 1.72$ ,  $p = .09$ ,  $d = .51$ , but significantly in SAS scores,  $t(46) = 25.08$ ,  $p < .001$ ,  $d = 7.24$ . Except for 2 non-fearfuls, all participants were female.

### Materials and procedure

The materials and the procedure of Experiment 2 were similar to Experiment 1. The only difference was that in the IVE part, after the object appeared and started to approach the participant, she could press the same button again to stop the object and make it disappear. Thus, the first button press would lift the corresponding box (as in Experiment 1), and the second press would make the object under the box disappear. We did not want participants to use this option merely to speed up the experiment, therefore the second button press only made the object disappear earlier, while the duration of each trial was still 7 s as Experiment 1. For instance, when a participant made a spider disappear after 1 s, she had to wait for another 6 s before a beep would signal that she could lift the next box. The time between appearance of the object and pressing the termination button was measured to assess if and how quickly participants escaped from the object.

## Results

### Was avoidance exhibited?

To answer this question, we again analyzed how often the SB and the TB were opened by the participants, using a repeated-measures ANOVA with the between-subjects factor “group” (spider-fearfuls vs. non-fearfuls) and the within-subjects factor “box” (SB

vs. TB). As in the first experiment, a significant interaction of group and box was found,  $F(1,46) = 20.43$ ,  $p < .001$ ,  $\eta^2 = .31$ . As predicted, spider-fearfuls preferred to lift the SB over the TB ( $t(23) = 4.38$ ,  $p < .001$ ,  $d = 1.79$ ), while non-fearfuls did not show any preference,  $t(23) = 1.53$ ,  $p = .14$ ,  $d = .55$  (see Table 2). This way, spider-fearfuls did indeed manage to encounter fewer spiders than non-fearfuls did (24.1 spiders vs. 27.4 spiders)  $t(46) = 4.56$ ,  $p < .001$ ,  $d = 1.32$ . In sum, these results replicate those of Experiment 1.

### How did avoidance develop over time?

To answer this question, we used the same approach as in Experiment 1: The 60 experimental trials were divided into 3 blocks in the first half and 3 blocks in the second half. For each block, the probability of encountering spiders (PES) was computed, and the PES were analyzed using the repeated-measures ANOVA with “half” and “block” as within-subjects factors and “group” as between-subjects factor (see Table 2). We found a significant main effect of group,  $F(1,46) = 23.15$ ,  $p < .001$ ,  $\eta^2 = .34$ , and a

**Table 2.** The mean number of lifted boxes, the reaction time to terminate approaching objects, the probability of encountering spiders (PES), and the estimated PES for each box, for spider-fearfuls and non-fearfuls in Experiment 2.

	Spider-fearfuls (SD)	Non-fearfuls (SD)
Lifted SB	22.1 (4.0)	18.6 (2.0)
Lifted TB	16.3 (3.4)	19.9 (2.7)
RT to stop cars in 1st half (sec)	7.2 (.8)	6.7 (.7)
RT to stop spiders in 1st half (sec)	6.8 (.7)	6.4 (.6)
RT to stop cars in 2nd half (sec)	6.7 (.6)	6.2 (.5)
RT to stop spiders in 2nd half (sec)	6.4 (.5)	6.2 (.4)
PES in Block 1 (%)	45.7 (6.8)	47.6 (6.6)
PES in Block 2 (%)	41.0 (9.9)	45.6 (5.1)
PES in Block 3 (%)	40.0 (8.1)	50.8 (8.6)
PES in Block 4 (%)	46.4 (7.6)	46.6 (6.2)
PES in Block 5 (%)	44.8 (9.7)	48.3 (6.6)
PES in Block 6 (%)	38.1 (12.7)	49.1 (10.2)
Estimated PES in SB (%) in 1st half	33.6 (18.8)	39.6 (22.3)
Estimated PES in NB (%) in 1st half	44.3 (16.0)	34.2 (19.3)
Estimated PES in TB (%) in 1st half	57.2 (22.6)	55.4 (24.7)
Estimated PES in SB (%) in 2nd half	39.4 (22.9)	48.9 (22.2)
Estimated PES in NB (%) in 2nd half	46.7 (14.3)	44.5 (13.1)
Estimated PES in TB (%) in 2nd half	52.5 (21.4)	56.8 (20.5)

Note: SB = Safe Box, NB = Neutral Box, TB = Threat Box, RT = Reaction Time.

significant group-by-block interaction,  $F(2,92) = 11.44$ ,  $p < .001$ ,  $\eta^2 = .20$ . The other main effects and interactions were not significant (all  $p > .07$ , all  $\eta^2 < .06$ ). The significant effects indicate that overall, spider-fearfuls were less likely to encounter spiders than non-fearfuls were, and that the two groups showed different developmental patterns of PES during the task.

To identify these patterns for each group and half, four repeated-measures ANOVAs were conducted with “block” as a within-subjects factor. The polynomial contrasts revealed that spider-fearfuls showed a decreasing linear trend in both the first and the second half (first half:  $F(1,23) = 9.64$ ,  $p = .005$ ,  $\eta^2 = .30$ ; second half:  $F(1,23) = 6.63$ ,  $p = .02$ ,  $\eta^2 = .22$ ), while non-fearfuls showed a quadratic trend with a lower middle point in the first half,  $F(1,23) = 8.24$ ,  $p = .009$ ,  $\eta^2 = .26$ , and no significant trend in the second half. These trend analyses illustrate that spider-fearfuls reduced their probability to encounter spiders in both halves of the task, which indicates that avoidance learning took place both at the beginning of the task and after the secret switch of probabilities.

Additionally, a MANOVA was computed to further investigate the differences between spider-fearfuls and non-fearfuls in each block. Significantly lower PES for the spider-fearfuls were found in Block 2,  $F(1,46) = 4.08$ ,  $p = .05$ ,  $\eta^2 = .08$ , Block 3,  $F(1,46) = 19.45$ ,  $p < .001$ ,  $\eta^2 = .30$ , and Block 6,  $F(1,46) = 11.05$ ,  $p = .002$ ,  $\eta^2 = .19$ , but not in the other three blocks, all  $F(1,46) < 1.07$ ,  $p > .15$ ,  $\eta^2 < .05$ ). Hence, it seems that in each half, spider-fearfuls needed at least one block to learn how to reduce their PES.

### *Were there differences in escape behaviour?*

To investigate escape behaviour, the reaction time for the use of the termination button was used as the dependent variable in a repeated-measures ANOVA with “object” (spiders vs. cars) and “half” as within-subject factors and “group” as between-subjects factor. If the termination button was not used, the RT was set to 7 s, the time it took until the object appeared automatically.

All main effect were significant: The participants more quickly terminated the spider than the car,  $F(1,46) = 14.73$ ,  $p < .001$ ,  $\eta^2 = .24$ ; they terminated the objects more quickly in the second half than in the first half,  $F(1,46) = 41.58$ ,  $p < .001$ ,  $\eta^2 = .48$ ; and the spider-fearfuls were generally slower to press the termination button than non-fearfuls,  $F(1,46) = 7.40$ ,

$p = .009$ ,  $\eta^2 = .14$  (see Table 2). In contrast, none of the interactions was significant, all  $F(1,46) < .88$ ,  $p > .35$ ,  $\eta^2 < .02$ . Hence, in contrast to our hypothesis, spider-fearfuls did not show faster escape than non-fearfuls, neither for spiders nor for toy cars.

### *Were there differences in competence?*

Post-experimental knowledge of the PES for each box in each half was measured and analyzed as in the first experiment. The ANOVA with the between-subjects factor “group” and the within-subjects factors “half” and “box” (SB, NB, TB) yielded a significant main effect of box,  $F(2,92) = 16.50$ ,  $p < .001$ ,  $\eta^2 = .26$ , because participants correctly estimated that the TB contained more spiders than the NB, which in turn contained more spiders than the SB (see Table 2). The main effect of group was not significant ( $F(1,46) = .11$ ,  $p = .74$ ,  $\eta^2 = .002$ ), indicating that spider fearfuls did not overestimate the overall probability to encounter spiders. Inspection of the means shown in Table 2 suggests that the two groups did indeed behave very similarly.

## **Discussion**

The results of Experiment 2 replicated the findings of Experiment 1: Spider-fearfuls showed significantly more avoidance of spiders than non-fearfuls, while the two groups had similar knowledge about the PES. Moreover, in line with our expectation, the more trials spider-fearfuls completed, the better they could avoid being exposed to spiders. This was true for both halves of the task. Thus, as in Experiment 1 we found differences in performance, but no differences in competence, lending support to the equal-learning hypothesis. It seems that both groups learned about the PES of each box, but only spider-fearfuls were motivated to use this knowledge to avoid spiders. Different from our hypothesis, however, spider-fearfuls did not show more escape behaviour than non-fearfuls. Overall, spider-fearfuls were slower than non-fearfuls to press the termination button, and both groups terminated the approaching spider more quickly than the approaching toy car.

## **Experiment 3**

The results of the first two experiments suggest that spider-fearfuls quickly learn to avoid exposure to spiders. They consistently showed more avoidance than non-fearfuls in both experiments. Moreover, the



differences in avoidance were observed despite comparable knowledge about the probabilities of encountering spiders under the different boxes. We concluded that in both experiments, improved performance in avoidance behaviour occurred in the absence of improved competence. It seems that fear of spiders did not lead to improved learning of probabilities, but to increased motivation to use the acquired knowledge. However, this conclusion may be premature, and limited to the extreme probabilities used in Exps. 1 and 2. Since the probabilities differed greatly from each other, with 90% for the threat box and only 10% for the safe box, it was probably quite easy to detect the difference between them. Thus, maybe even the least motivated non-fearful participant could not help but notice the differences between the 3 boxes. Therefore, in Experiment 3, we modified the probability of encountering spiders for each box, to make the differences among the three boxes more difficult to detect. By making the percentages less extreme, we could avoid a floor effect in difficulty. We aimed to find out whether in this more difficult situation, spider fearfuls would still be sensitive to the differences in probabilities, both by showing more avoidance of spiders (performance), and possibly also by better knowledge of the probabilities than non-fearfuls (competence).

## Methods

### Participants

Sixty-three female students (mean age 20.8 years, range 18–32) of Radboud University Nijmegen were recruited for a pre-screening with the SAS (Rinck et al., 2002). Based on the large effect observed in Exp. 1 ( $\eta^2 = .28$ ), 18 participants in total would yield sufficient statistical power. However, because of the more subtle differences between the three boxes, we expected a smaller effect size in Exp. 3. Hence, we aimed for a similar sample size as in Exps. 1 and 2, to make the three experiments more comparable. As a result, 20 spider-fearful participants (mean SAS score = 20.2, SD = 2.1) and 23 non-fearful ones (mean SAS score = 4.0, SD = 2.1) were selected. As in the previous experiments, spider-fearfuls and non-fearfuls did not differ in age,  $t(41) = .60$ ,  $p = .55$ ,  $d = .18$ , but significantly in SAS scores,  $t(41) = 25.04$ ,  $p < .001$ ,  $d = 7.65$ .

### Materials and procedure

The materials and procedure were highly similar to those of Experiment 1. The main differences concerned

the probability of encountering spiders for each box, and the overall number of trials. In the first half of the task, participants had a 30% chance to find a spider in the SB, 70% in the TB, and 50% in the NB. After secretly swapping SB and TB, the new SB housed 40% spiders, the TB housed 60%, and the NB still housed 50% spiders. Thus, compared to Exps. 1 and 2, the probabilities differed less in the first half (40% here vs. 80% earlier), and even less in the second half (20%), making it even more difficult to realise the difference. Taking this increased difficulty into account, we doubled the number of trials in Experiment 3, to allow for the observation of a potentially slower learning process (i.e. 60 instead of 30 trials in each half).

## Results

### Was avoidance exhibited?

To answer this question, we again analyzed how often the SB and the TB were opened by the participants, using the repeated-measures ANOVA with the between-subjects factor “group” (spider-fearfuls vs. non-fearfuls) and the within-subjects factor “box” (SB vs. TB). Unlike the first experiments, neither a significant main effect of box,  $F(1,41) = 1.19$ ,  $p = .28$ ,  $\eta^2 = .03$ , nor a significant box-by-group interaction was found,  $F(1,41) = 2.38$ ,  $p = .13$ ,  $\eta^2 = .06$ . In fact, neither spider-fearfuls nor non-fearfuls showed a significant preference for the safe box (spider-fearfuls:  $t(19) = 1.67$ ,  $p = .11$ ,  $d = .38$ ; non-fearfuls:  $t(22) = .36$ ,  $p = .73$ ,  $d = .08$ , see Table 2). Similarly, when the total number of spiders encountered during the task was analyzed, spider-fearfuls did not see significantly fewer spiders than non-fearfuls (60.3 spiders vs. 60.5 spiders),  $t(41) = .13$ ,  $p = .90$ ,  $d = .04$ .

### Did choice behaviour change over time?

Although no overall difference in avoidance was found between the two groups, we still aimed to find out whether the participants’ choices, and thereby their probability of encountering spiders (PES), changed across the 12 blocks of the task. The PES were calculated with the same formula as in Experiments 1 and 2, although here for 12 blocks rather than for 6 blocks. As in the previous experiments, we first conducted a repeated-measures ANOVA with the between-subjects factor “group” and the within-subject factors “half” and “block”. The only significant effect in this analysis was the main effect of group,  $F(1,41) = 4.75$ ,  $p = .04$ ,  $\eta^2 = .10$ , because in general, spider-fearfuls had a slightly

lower probability of encountering spiders than non-fearfuls had (49.4% vs. 50.1%) As in the previous experiments, we also conducted a repeated-measures ANOVA with the factor “block” for each group and half separately, in order to examine the time course of PES more closely. However, here the contrasts indicated no fitted trend in any group or half, suggesting that neither group showed a discernable pattern in the development of PES.

### Were there differences in competence?

Post-experimental knowledge of the PES for each box in each half was measured and analyzed as in the earlier experiments. The ANOVA with the between-subjects factor “group” and the within-subjects factors “half” and “box” (SB, NB, TB) yielded a significant main effect of box,  $F(2,78) = 5.43$ ,  $p = .006$ ,  $\eta^2 = .12$ , because on average, participants correctly estimated that the TB contained more spiders than the NB, which in turn contained more spiders than the SB (see Table 3). The main effect of group was not significant, and neither was any of the interactions, all  $F < 1.99$ ,  $p > .14$ ,  $\eta^2 < .05$ , indicating that the two groups’ estimations were very similar (see Table 3).

**Table 3.** The mean number of lifted boxes, the probability of encountering spiders (PES), and the estimated PES for each box, for spider-fearfuls and non-fearfuls in Experiment 3.

	Spider-fearfuls (SD)	Non-fearfuls (SD)
Lifted SB	39.5 (11.4)	39.1 (5.1)
Lifted TB	36.4 (9.7)	39.6 (4.7)
PES in Block 1 (%)	49.8 (4.3)	50.3 (2.3)
PES in Block 2 (%)	48.3 (6.1)	50.6 (3.3)
PES in Block 3 (%)	47.9 (4.1)	50.5 (3.6)
PES in Block 4 (%)	48.0 (4.6)	50.6 (5.0)
PES in Block 5 (%)	48.6 (5.0)	51.0 (4.0)
PES in Block 6 (%)	48.5 (7.6)	50.3 (4.9)
PES in Block 7 (%)	50.2 (2.3)	49.2 (2.6)
PES in Block 8 (%)	50.6 (2.6)	50.1 (2.8)
PES in Block 9 (%)	50.5 (2.4)	49.5 (2.1)
PES in Block 10 (%)	50.5 (3.2)	50.1 (2.2)
PES in Block 11 (%)	50.0 (3.0)	50.0 (2.0)
PES in Block 12 (%)	49.8 (2.9)	49.6 (2.4)
Estimated PES in SB (%) in 1st half	38.2 (17.1)	42.1 (14.8)
Estimated PES in NB (%) in 1st half	50.5 (18.5)	48.4 (14.5)
Estimated PES in TB (%) in 1st half	57.6 (14.9)	56.8 (16.2)
Estimated PES in SB (%) in 2nd half	56.3 (16.1)	49.6 (10.0)
Estimated PES in NB (%) in 2nd half	57.1 (18.7)	51.1 (16.8)
Estimated PES in TB (%) in 2nd half	49.0 (16.3)	54.8 (12.5)

Note: SB = Safe Box, NB = Neutral Box, TB = Threat Box.

## Discussion

In line with our predictions, Experiment 3 revealed that spider-fearfuls had a slightly lower PES than non-fearfuls. Moreover, we replicated the finding that the two groups showed similar estimates of the PES, suggesting comparable competence. However, the difference in actually experienced PES was much smaller than in the previous experiments, and there were no significant differences in the lifted boxes or the number of encountered spiders. Thus, we may conclude that the increased difficulty of Experiment 3 – with its reduced difference between the PES of the safe box and the threat box – made it almost impossible for spider-fearfuls to learn how to avoid spiders.

## General discussion

Our goals in the present study were to examine: (1) Spider-fearfuls’ and non-fearful controls’ performance regarding the avoidance of and escape from spiders; and (2) spider-fearfuls’ and non-fearfuls’ competence regarding the knowledge that is needed to show avoidance. In three experiments, an immersive virtual environment was used in which participants needed to lift virtual boxes, under which either a virtual spider or a virtual car appeared and approached the participant. By analyzing the frequency of lifting each box and the resulting probability of encountering spiders (PES), we found strong evidence of *avoidance* in spider-fearfuls, but not in non-fearfuls. Specifically, the results of the first two experiments consistently demonstrated that spider-fearfuls managed to reduce the threat of encountering spiders by lifting the safe box more often and the threat box less often than non-fearfuls did. The results of Experiment 3 point to the limits of this avoidance learning: When the percentages of spiders hidden under the safe box and under the threat box became very similar (most clearly so in the second half of Exp. 3), spider-fearfuls were not able anymore to choose the safe box more often. In contrast to our predictions, however, in Experiment 2, spider-fearfuls did not *escape* from spiders more often than from the neutral toy car. In fact, compared to non-fearfuls, spider-fearfuls took more time to make both threatening and neutral objects disappear. Finally, regarding the second research question addressing *competence*, the three experiments revealed highly consistent results: Spider-fearfuls and non-fearfuls showed very similar post-experimental

knowledge about the probability of encountering spiders under each box.

The present study is among the first to separate avoidance from escape when studying fearful participants in a laboratory experiment. While escape from threatening events and situations has frequently been studied, avoidance of a forthcoming aversive event has hardly ever been investigated, especially in a controlled laboratory environment. An exception was reported by Rinck et al. (2015); in their study spider-fearful participants could use their knowledge of a virtual environment to avoid exposure to spiders. Together with escape, avoidance is the most relevant defensive behaviour for people with fears and phobias (Mowrer, 1939; Rachman, 1976). Avoidance (e.g. not going into a spider-infested attic) may be viewed as “smarter” than escape (e.g. leaving the attic when seeing a spider there) because it prevents the anxiety-provoking situation from occurring rather than merely ending it. However, avoidance also maintains the symptoms of anxiety, because it prevents fearfulness from experiencing habituation and from discovering that exposure is not as threatening and overwhelming as expected. Hence, both avoidance and escape should be studied, in order to understand the underlying mechanisms of fears and phobias.

Another noteworthy aspect of the present study is the distinction between competence and performance in avoidance learning. Competence refers to the knowledge and abilities people have, while performance refers to the behaviour they actually show. Competence is the “root” of performance (Wood & Power, 1987), but differences in performance do not necessarily indicate corresponding differences in competence. In the present experiments, we therefore aimed to investigate differences between spider-fearfuls and non-fearfuls in both competence and performance. Participants’ performance was measured by observing the boxes they lifted, while their competence was assessed by measuring their knowledge of the probability of encountering spiders (PES) under each box. In all studies, spider-fearfuls and non-fearfuls showed comparable post-experimental knowledge about the PES, which suggests that there were no differences in competence. This result is hard to explain by the improved-learning hypothesis or the selective-learning hypothesis. Instead, it seems that both groups acquired similar levels of knowledge, while only spider-fearfuls used the knowledge to avoid

encounters with spiders, as predicted by the equal-learning hypothesis.

Discrepancies between competence and performance (here: not showing a behaviour that one is capable of) can be caused by many different external or internal factors (Dillon & Stevenson-Hicks, 1983; Sophian, 1997; Wood & Power, 1987). In the present experiments, the impact of external factors could be minimised because of the strict control of the experimental setting. Instead, the discrepancy between competence and performance shown by non-fearful controls can be explained by an internal factor, namely lack of motivation: They were able to avoid spiders, but presumably felt no need to do so. In contrast, spider-fearfuls have a strong motivation to apply the acquired knowledge because it allows them to avoid the anxiety-provoking confrontation with spiders.

Experiment 3 showed that there are limits to avoidance learning, too. Although we may assume that the participants of this experiment were as motivated to avoid spiders as the participants of the previous experiments, they found it very difficult to do so, particularly in the second half of the experiment when the PES of the three boxes were very similar. Even though we doubled the number of trials compared to the previous experiments, it seems that the number was still insufficient for successful avoidance learning. In addition, the increased difficulty might have reduced the spider-fearfuls’ motivation to identify the box with the fewest spiders under it: Given that there was no really “safe” box with very few spiders, and that the difference between safe box and threat box became quite small (40% vs. 60% spiders in the second half), the spider-fearfuls might have given up their attempts to avoid spiders. We are confident that the insignificant effects observed in Exp. 3 were due to the very subtle differences among the three boxes, because this experiment had similar statistical power as Exps. 1 and 2.

It is worth mentioning that in Experiment 2, spider-fearfuls did not show escape behaviour, that is, they did not make the approaching spider disappear more quickly than the approaching toy car. In fact, they took longer than non-fearfuls to press the termination button for both spiders and toy cars. This result is difficult to explain post-hoc, and it contradicts previous studies of escape behaviours (e.g. Garcia-Palacios et al., 2002; Pflugshaupt et al., 2005; Rinck & Becker, 2007). In those studies, escape was found repeatedly in both controlled processes and in automatic processes. The reasons for these contradictory

findings is not entirely clear. First, it may be relevant that the current study is the only one in which both avoidance and escape were possible. Thus, quick escape from threat may be less urgent when the possibility to avoid exposure has already reduced anxiety to a bearable level. In contrast, our unexpected finding might be caused by another type of defensive behaviour: freezing. Several studies showed a human freezing reaction in response to aversive stimuli (Blanchard, Flannelly, & Blanchard, 1986; Eilam, 2005; Hagenaars, Roelofs, & Stins, 2014). One may therefore speculate whether spider-fearfuls were slow to press the termination button because they showed a freezing reaction in the threatening environment. However, this hypothesis cannot easily explain why previous studies revealed faster escape by fearfuls, and why the spider-fearfuls in our Experiment 2 were also slow to terminate harmless toy cars. The absence of escape behaviour in Exp. 2 might also be due to the setting in an IVE which required escape by means of a button press to make the spiders disappear. This escape behaviour is quite unnatural compared to real escape behaviour in response to real spiders (e.g. leaving the room). In contrast, Mühlberger, Sperber, Wieser, and Pauli (2008) successfully induced escape behaviours in an IVE-based BAT in spider-fearfuls, probably because the escape behaviour in their study resembled actual escape behaviour. Finally, our reaction time findings should be interpreted cautiously because spider-fearfuls encountered fewer spiders and more toy cars than non-fearfuls (due to successful avoidance learning), meaning that the computed mean times to terminate approaching objects were based on differing numbers of cases.

Last but not least, the present experiments add to a growing number of studies which demonstrate that IVEs have specific advantages when it comes to the study of specific fears and phobias. First, IVEs provide a standardised and controlled situation in which independent variables can be controlled, possibly confounding variables can be held constant, and important dependent variables can be measured (Wiederhold & Bouchard, 2014). Of course this high internal validity of IVEs must be accompanied by high external validity, that is, virtual environments should elicit similar emotional and behavioural responses as real environments. In specific fears and phobias, many studies have shown that this is indeed the case, suggesting that spider-fearfuls' responses to virtual spiders resemble their responses to real spiders, including

avoidance of them (Mühlberger et al., 2008; Rinck et al., 2010, 2015). Hence, IVEs could be applied in various measurement and treatment situations that target specific phobias (Mühlberger et al., 2008).

Several limitations of the present studies deserve mentioning. First of all, the current participants were highly spider-fearful, but were not clinically diagnosed with spider phobia. This fact weakens the implications of the present findings for clinical samples. Future studies should therefore recruit diagnosed spider phobics to test whether our results generalise to more severe cases. Secondly, our conclusion that spider-fearfuls and non-fearfuls exhibited comparable competence levels is based on the finding that they did not differ in post-experimental knowledge. This, however, does not rule out the possibility that spider-fearfuls acquired this knowledge more quickly, which would have given them higher competence during part of the experiment. Measuring the participants' knowledge after the experiment only was necessary to avoid interference with the performance measures during the task. However, for measuring competence, it was clearly a compromise, and future studies should address this problem by focusing on the repeated measurement of participants' knowledge during the task.

In conclusion, the present study provides evidence of avoidance learning in spider-fearful participants in a controlled laboratory setting employing virtual reality techniques. In addition, the present study is one of the first to address both competence and performance, and within performance, it separates avoidance from escape. In doing so, the three experiments reported here suggest that with regard to avoidance learning, spider-fearfuls differ from non-spider-fearfuls in performance, but not necessarily in competence: Even if both groups have the knowledge needed for avoidance, only fearfuls are motivated to use it to avoid threat.

## Note

1. To calculate the effect size for within-subjects *t*-tests, we used the equation:

$$d = \frac{M_1 - M_2}{\sqrt{SD_1^2 + SD_2^2 - 2 \times SD_{1,2}}}$$

To calculate the effect size *d* for between-subjects *t*-tests, we used the equation:

$$d = \frac{\text{Abs}(M_{\text{group1}} - M_{\text{group2}})}{\text{Mean}(SD_{\text{group1}}, SD_{\text{group2}})}$$

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